

The AGTSR Industry-University Connection

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Introduction

The Advanced Gas Turbine Systems Research (AGTSR) program is a national industry-university R&D consortium dedicated to supporting the advancement of land-based gas turbines for future power generation systems which include both the ATS and post-ATS technology base programs. This unique consortium is managed and administered by the South Carolina Energy R&D Center (SCERDC), which is housed at Clemson University. The AGTSR consortium is sponsored by DOE-Federal Energy Technology Center and is scheduled to continue until the year 2001.

AGTSR encompasses both an educational and research component. The educational program consists of undergraduate fellowships and graduate-level industrial internships at sponsoring company sites. To date, AGTSR has placed thirty-seven interns at some of the major gas turbine facilities throughout the United States. The internship experience motivates engineering students to pursue gas turbine careers and allows them to gain valuable hands-on experience in an industrial setting. The research arm of AGTSR nurtures collaborative R&D with universities and industry. All the research issues identified by AGTSR are defined by the Industry Review Board (IRB) which consists of representatives from the gas turbine manufacturers.

Presently, there are 92 performing member universities representing 37 states, and seven cost-sharing U.S. gas turbine/component corporations. The industrial members are Allison Engine Company, General Electric, Parker Hannifin, Pratt & Whitney, Solar Turbines, Southern Company Services, and Westinghouse Electric Corporation. The Electric Power Research Institute and the Gas Research Institute continue to act in an advisory role for the AGTSR consortium. AGTSR also coordinates with the Department of Defense and NASA on gas turbine research programs of mutual interest. Five Request for Proposals (RFP) have been announced and the sixth RFP is expected to be released in March, 1998.

Over the past five years, AGTSR has supported 41 research subcontracts at performing member universities, and ten new projects selected from the 1997 RFP are tentatively scheduled to begin in January, 1998.

The AGTSR research consortium is sponsored by the U.S. Department of Energy, Federal Energy Technology Center, under Cooperative Agreement No. DE-FC21-92MC29061. Period of Performance: January 1, 1997, to December 31, 1997.

AGTSR has also organized and hosted nine workshops, five in the combustion area, two in heat transfer, and one in materials and sensors and controls. The next AGTSR combustion workshop will be hosted with the University of California, Berkeley, and is scheduled for March 25-27, 1998, in Berkeley, CA. AGTSR's second materials workshop will focus on thermal barrier coatings and is being planned for May or June 1998, hosted with Stevens Institute of Technology. The third heat transfer workshop will be hosted with the University of Texas, Austin, and is tentatively scheduled for the late fall of 1998.

The AGTR Industrial Internship Program (IIP) has obtained very favorable reviews from the IRB and several of the interns participating in the program have taken positions in U.S. gas turbine companies upon graduation. IIP targets MS and PhD students interested in gas turbine R&D, however, post-docs and graduating seniors are also eligible to apply. In December, 1997, the next IIP brochure will be distributed to all AGTSR performing member universities. Applications will be due to AGTSR in early March, 1998. Selected interns will begin working at ATS company sites in early June, 1998. For the summer of 1998, the internship period will be increased from 10 weeks to 12 weeks, at a weekly stipend of \$450 per week. A \$1000 allowance is also provided to help offset round-trip travel and relocation expenses.

The AGTSR consortium continues to nurture close industry-university collaborations to enhance synergism and the transition of research results, accelerate and promote evolutionary-revolutionary R&D, and advocate advanced technology development for future power generating markets on a worldwide basis.

Background

In 1992, the U. S. Department of Energy (DOE) initiated a program to develop advanced gas turbine systems for power generation in utility and industrial applications. The Advanced Turbine Systems (ATS) program is jointly sponsored by DOE Fossil Energy and DOE Energy Efficiency and Renewable Energy. The primary focus of ATS is presently on natural gas fired turbines but adaptation to coal and biomass derived fuels is a consideration. The ATS program, initiated in 1992, is a multi-year activity that involves turbine manufacturers, utilities, end-users, and universities. One of the supporting elements of the ATS is the Advanced Gas Turbine Systems Research (AGTSR) program. The AGTSR is an industry driven, nationwide, university consortium designed to conduct technology base R&D to support the overall ATS program.

The South Carolina Energy Research and Development Center (SCERDC) has administered the AGTSR since ATS program startup in 1992. SCERDC applied for and received AGTSR program renewal from DOE-FETC for the cooperative agreement in 1997. SCERDC has also sought continuation of that agreement for calendar year 1998.

Since inception, the AGTSR has been sponsored by the Federal Energy Technology Center (formerly the Morgantown Energy Technology Center). The Industrial Review Board (IRB) has increased from four founding member companies to, at various times, include the following:

+Allison Engine Company	+General Electric	-Southern Company Services
AlliedSignal	-Parker-Hannifin	+Solar Turbines, Inc.
Fluor Daniel	+Pratt & Whitney	+Westinghouse

The designation next to the company indicates: (+) voting board member, and (-) non-voting member. AlliedSignal and Fluor Daniel had IRB membership for one year. AlliedSignal may renew their membership in fiscal year 1998. EPRI and GRI have been program advisors since inception.

The Performing Member university base has been expanded from eleven initial university members to approximately 92 university members, as shown in Table I.

Table I
AGTSR Performing Members

Air Force Institute of Technology, Ohio	Western Michigan University, Michigan
University of Alabama, Alabama	University of Minnesota, Minnesota
University of Arkansas, Arkansas	University of Missouri-Rolla, Missouri
Arizona State University, Arizona	Massachusetts Inst. of Technology, MA
Auburn University, Alabama	State University of NY, Stony Brook, NY
Brigham Young University, Utah	NC State University, North Carolina
State University of NY, Buffalo, NY	Northeastern University, Massachusetts
California Institute of Technology, CA	Northwestern University, Illinois
Univ. of California, Berkeley, CA	University of Notre Dame, Indiana
Univ. of California, Davis, CA	Ohio State University, Ohio
Univ. of California, Irvine, CA	University of Oklahoma, Oklahoma
Univ. of California, San Diego, CA	Pennsylvania State University, PA
Univ of California, Santa Barbara, CA	University of Pittsburgh, Pennsylvania
Carnegie Mellon University, PA	Polytechnic University, NY
University of Central Florida, Florida	Princeton University, New Jersey
University of Cincinnati, Ohio	Purdue University, Indiana
Clarkson University, NY	Rensselaer Polytechnic Institute, NY
Clemson University, South Carolina	University of South Carolina, SC
Cleveland State University, Ohio	Southern University, Louisiana
University of Colorado, Boulder, CO	University of Southern California, California
Univ. of Connecticut, Connecticut	University of South Florida, Florida
Cornell University, NY	Stanford University, California
University of Dayton, Ohio	Stevens Institute of Technology, New Jersey
University of Delaware, Delaware	Syracuse University, NY
University of Denver, Colorado	Tennessee Technological University, TN
Drexel University, Pennsylvania	University of Tennessee, Tennessee
Duke University, North Carolina	University of Tennessee Space Institute, TN
Embry Riddle Aeronautical Univ., Florida	Texas A&M University, Texas
Florida Atlantic University, Florida	University of Texas, Arlington, Texas
Florida Institute of Technology, Florida	University of Texas, Austin, Texas
Georgia Tech, Georgia	University of Tulsa, Oklahoma
University of Hawaii, Manoa, Hawaii	University of Utah, Utah
University of Houston, Texas	Vanderbilt University, Tennessee
University of Illinois, Chicago, Illinois	Virginia Polytechnic Institute, Virginia
Iowa State University, Iowa	Washington University, Missouri

University of Iowa, Iowa	University of Washington, Washington
University of Kansas, Kansas	Wayne State University, Michigan
University of Kentucky, Kentucky	Western Michigan University, Michigan
Lehigh University, Pennsylvania	West Virginia University, West Virginia
Louisiana State University, Louisiana	University of Wisconsin, Madison, WI
Univ. of Maryland, College Park, MD	University of Wisconsin, Milwaukee, WI
Univ. of Massachusetts, Lowell, MA	Wichita State University, Kansas
Mercer University, Georgia	Worcester Polytechnic Institute, MA
Michigan State University, Michigan	Wright State University, Ohio
Michigan Technological Univ., Michigan	University of Wyoming, Wyoming
University of Michigan, Michigan	Yale University, Connecticut

Note: Universities in bold type have received AGTSR subcontracts.

The AGTSR program has expanded from a strict research base to a multi-faceted program that includes research and technology transfer functions. Research directed by the IRB and performed by the university membership continues to be the program's main thrust. However, to promote research relevance and collaboration, workshops, faculty fellowships, student internships, undergraduate fellowships and short courses have been established. Since 1992, AGTSR has supported 51 research programs, 10 workshops, numerous student interns and fellowships, one faculty fellowship and one short course.

The AGTSR consortium strives to enhance U.S. competitiveness through close relations with industry, universities, and government. AGTSR is in its sixth year of operation and is sponsored by the U.S. Department of Energy—Federal Energy Technology Center, Morgantown, West Virginia.

The two major goals of the AGTSR consortium are: to promote industry-oriented collaborative R&D with American universities supporting industry's research needs in advanced land-based gas turbine systems; and secondly, to promote multi-disciplinary engineering education with various technical disciplines and teams working together to contribute to the Advanced Turbine Systems (ATS) technologies necessary to realize gas turbine challenges for the 21st century.

In particular, the AGTSR consortium nurtures the following objectives:

- actively contribute to the fundamental research needs of ATS and post-ATS programs for both industrial and utility applications
- foster long-lasting industry-university collaboration and strive to accelerate the transition of research results to ATS and future growth power generation systems
- increase gas turbine-power generation research activities at American universities and promote collaborative R&D with professors and their students developing fundamental projects focused on industry-defined issues

- promote an educational mission by sponsoring undergraduate, graduate, and faculty-level internships at industrial laboratories or government facilities
- co-sponsor seminars, workshops, short-courses, and specialty-topic meetings that directly contribute to the needs of the ATS program.

The AGTSR consortium is viewed as a synergetic program dedicated to injecting fresh ideas and higher-risk research concepts from universities to industry's advanced technology programs. The AGTSR central theme is to promote collaborative R&D and interdisciplinary research and education in the gas turbine-power generation area. AGTSR encourages strong university-industry alliances in all of their research activities. These alliances will enable closer ties and interactions with respect to focused research activity and new educational opportunities to support the next frontier of land-based gas turbines, enhance U.S. competitiveness in the global market, and prepare us to meet 21st century demands for advanced electrical power generation systems. AGTSR believes that consortia are a cost effective way of doing generic R&D in support of industry, and the AGTSR consortium strives to keep its research programs relevant and closely coordinated with industry, but not at the expense of eliminating the fundamental and scientific aspects and curiosities of university-based investigations.

To ensure that the advanced technology is incorporated into future systems and to keep the United States a world leader of gas turbine engines, the Department of Energy is aggressively working with U.S. gas turbine manufacturers in an 8-year program to develop an advanced, ultra-high efficiency, environmentally superior turbine system that will be less expensive and more reliable than today's systems.

The Advanced Gas Turbine Systems Research (AGTSR) program is considered a subset of the Advanced Turbine Systems (ATS) prototype program. The AGTSR consortium is closely tied to ATS and post-ATS technology needs and has the potential to strongly impact the future design of land-based gas turbine systems. AGTSR was established to pursue, in a concerted fashion, the research needs as defined by the ATS industry. AGTSR is a valuable resource that promotes collaborative R&D and multidisciplinary education in coordination with industry, university, and government gas turbine R&D activities.

The major goals of ATS are:

- system efficiency (for combined cycles greater than 200MW) that will exceed 60 percent based on natural gas and a 15 percent improvement for simple cycle industrial applications (less than 20MW)
- environmentally superior systems with 9ppm (or less) NO_x levels
- busbar energy costs that are at least 10 percent less than current state-of-the-art turbine systems
- fuel-flexible designs that will operate on natural gas but are also capable of being adapted to operate on coal, coal-derived, or biomass fuels.

Research Approach

The South Carolina Energy Research and Development Center (SCERDC) is coordinating and managing a consortium of 92 universities in 37 states that is providing gas turbine research advances and establishing a fundamental base of knowledge in this technology area. Under the Department of Energy's oversight, the consortium brings together the engineering and science departments of the nation's leading universities and the industrial

turbine developers to ensure that the next generation of natural gas turbines is built on a solid base of knowledge. The consortium was formed in 1992 and will continue through 2001. There are 41 university research subcontracts and 10 new awards to be awarded in early 1998. All university projects were recommended by the consortium's industrial members. Each focuses on obstacles applicable to the entire industry, and for which university research is most appropriate. The major R&D areas currently being emphasized include:

Materials

- single crystal casting processes
- advanced thermal barrier coatings
- steam-cooling issues

Combustion

- combustion instability, high pressure scaling
- lean premixed, low NO_x combustors
- catalytic combustion
- dual-fuel issues, fuel composition effects
- advanced sensors, active control designs

Heat Transfer

- disk-cavity cooling
- closed-loop steam/mist cooling
- advanced film-cooling designs
- internal/edge-cooling enhancement

Aerodynamics

- multi-stage rotor-stator interactions
- multi-disciplinary aero-thermal design
- controlling aero losses
- multi-parameter optimization

To date, many of these R&D issues are being pursued—in a collaborative fashion—by the AGTSR consortium and the payoff is to achieve higher operating temperatures, and more thermally efficient, environmentally benign and durable gas turbine systems. For a better appreciation of the scope of the research issues being pursued by AGTSR, one may refer to the AGTSR Workshop Proceedings in combustion, heat transfer, and materials as listed in the reference section of this paper.

A key element of the AGTSR is that it was developed to deal with real life issues facing the development of advanced gas turbine systems rather than being a group solely sponsoring interesting research. Because of this need, the Industrial Review Board (IRB) was established. The role of the IRB is to specify research needs, evaluate university proposals, recommend proposals for funding support, evaluate research results and to collaborate and interact with university research teams. The role and eligibility criteria to be a voting member of the IRB are more thoroughly explained in the AGTSR By-laws, which were published in March 1993, and since revised as of September 1996. The AGTSR By-laws are available upon request through the consortium.

The voting IRB members are cost-sharing at an annual contribution of \$25,000. It is expected that the voting IRB membership will remain intact for the duration of the AGTSR consortium—until the year 2001. Parker Hannifin and Southern Company Services are non-voting corporate members of the IRB. The IRB is augmented by representatives from ERPI, GRI and DOE. The later are non-voting, non cost-sharing participants. Presently, the Industrial Review Board includes the following:

Table II. IRB Members

Industrial Review Board (voting members)	Corporate Members
Allison Engine Company, Sy Ali	Parker Hannifin, Peter Buca, Curt Scheuerman
General Electric, Harold Miller	Southern Company Services, Charles Boohaker
Solar Turbines, George Padgett	
Pratt & Whitney, William Day	
Westinghouse, Ihor Diakunchak	

AGTSR Requests for Proposals (RFP) are solicited on an annual basis with industry defining and prioritizing generic gas turbine research topics that are relevant to their needs and considered high payoff technology areas by their designers and R&D experts. An industry subarea points-of-contact list has been generated for each of the major technical disciplines being targeted within AGTSR. These subarea contacts facilitate the coordination of specific research issues for each RFP and the evaluation of university proposals in various research areas. They also nurture industry-university collaboration at the R&D working level. Currently, the voting IRB members have a single focal point within each company that is not rotated. The focal point is responsible for coordinating the research issues and the evaluation of the various proposals with the appropriate R&D expert within his or her company. The U.S. Department of Energy (DOE) does not participate in the RFP proposal review process; however, they do evaluate the performance of the IRB and the AGTSR consortium through a required yearly annual review meeting. The DOE must also approve any IRB proposal recommendations before being supported by the consortium.

R&D department experts from the various IRB companies also help monitor the research projects and participate in the review of research progress at the AGTSR annual workshops. Also, the IRB company may compete for some of the consortium's funds through the RFP process. However, the university must take the lead in the research proposal and the IRB company must act as a subcontractor, but with the university requesting the bulk of the funding support—usually about 70 percent. If a particular IRB company is listed as a subcontractor on the proposal, then for that particular proposal, the company is excluded from voting on it.

The AGTSR mission to promote cooperation between universities-industry-government is working well. An extensive network has been formed via the research projects, the workshops, specialty meetings, education program, and general program notices that have resulted in significant cooperation and interaction.

During the AGTSR cooperative agreement with DOE-FETC, five RFP's have been prepared and released by AGTSR and two hundred and seventy-five proposals have been received and evaluated by the Industrial Review Board. Of the proposals reviewed, 41 research proposals were awarded subcontracts and 10 awards are pending approval from the FY97 RFP. Research summaries of all the active AGTSR projects are kept at SCERDC and have been distributed to the IRB and DOE. In FY97, fifty-two proposals were received with the following topical distribution: 22 combustion, 20 heat transfer, and 10 in materials. The FY97 proposals have been reviewed and a hierarchy established for possible funding. It is expected that the top 10 proposals will be awarded in January 1998, pending FY98 funding availability.

The ATS goal of developing advanced engines with high efficiencies directed the initial research program emphasis—combustion, heat transfer and materials. Over the life of the AGTSR, the research priority base will vary as objectives are satisfied or significant progress is made in selected areas. Research programs will continue throughout the duration of the AGTSR consortium, however, the exact research topics will be influenced by previous results, availability of funds, quality of proposals and IRB needs.

Some selected examples of research progress to date include:

- U-Conn applies for patent for heat pipe turbine vane cooling concept (P&W)
- Syracuse develops 3D viscous, inverse turbomachine blade design method (Solar)
- Georgia Tech develops novel combustion CVD technique for producing TBC's (GE)
- UC-Berkeley develops novel fiber optic probe for F/A mixedness measurements (GE, Solar)
- BYU develops new 3D, lean premixed, combustion model and user's manual (ATS)
- Georgia Tech develops active combustion control strategy (Westinghouse)
- Cal-Irvine characterizes practical swirl vanes for Westinghouse
- Cornell develops simplified chemistry model for Allison's PDF code
- Penn State tests fuel/air probe at FETC and Westinghouse
- Minnesota PI does heat transfer sabbatical at Solar Turbines for summer of 97
- Clarkson PI does heat transfer sabbatical at P&W for 97-98 academic year
- Texas A&M develops unsteady aero transition model for boundary layer codes
- Central Florida collaborates with Westinghouse on hot corrosion materials degradation
- Clemson develops CFD film-cooling design methodology (ATS)
- U-Conn implements new methods for TBC bond strength and stress measurements (ATS)
- Penn State collaborates with Allison on multistage unsteady aero models
- Purdue implements PIV to investigate 3D unsteady aerodynamics and heat transfer with Allison

Full progress reports of all research projects are available at SCERDC. The above listing is only selective in nature and not fully inclusive.

To promote technology transfer, it became very apparent that an effective mechanism for early discussion and release of research progress was necessary. The need existed for establishing the dialogue between university groups and with industry technical specialists. A newsletter, hotline and trial workshop in combustion were tried. The combustion workshop was found to be extremely worthwhile by all attendees; therefore, the workshop concept was expanded to other discipline areas. The workshop venue was organized to share research progress and results in an informal manner, to permit critiquing of research plans and approach, to disseminate information early in the work progress and to promote teaming between research groups.

See Table III for a listing of the workshops and specialty meetings that have been held by AGTSR.

Table III. AGTSR Workshops

<i>WORKSHOP</i>	<i>LOCATION/YEAR</i>	<i>WORKSHOP</i>	<i>LOCATION/YEAR</i>
Combustion Workshop I	Nashville, TN - 1994	Heat Transfer Workshop I	Hilton Head, SC - 1995
Combustion Workshop II	Indianapolis, IN - 1995	Heat Transfer Workshop II	Isle of Palms, SC - 1997
Combustion Workshop III	Lake Arrowhead, CA, '96	Combustion Instability I	State College, PA - 1995
Combustion Workshop IV	Atlanta, GA - 1997	Sensors and Controls	Clemson, SC 1996
Materials Workshop I	Charleston, SC - 1996		

All the AGTSR workshops and specialty meetings have attracted experts actively working in their respective R&D fields from industry, universities, and government laboratories. These workshops not only promote teaming at the R&D level, but also provide a valuable source of fresh research ideas and topics for possible inclusion into future RFP announcements.

Education Approach

The educational program consists of undergraduate fellowships and graduate-level industrial internships at sponsoring company sites. To date, AGTSR has placed 37 interns at some of the major gas turbine facilities throughout the United States. The internship program is a great vehicle for AGTSR students to get indoctrinated into industry needs and for industry to help aim their future studies in a direction that will help the student, the professor, and industry. It also provides industry with some fresh views on their own in-house research programs and advanced technologies.

The undergraduate fellowship program was initiated on a trial basis with Clemson and Clarkson University and the University of Minnesota. Its purpose was to expose juniors and seniors to AGTSR gas turbine research and to encourage them to continue on to graduate school pursuing an MS or PhD in a gas turbine specialty field. Its intent was also to entice the students to work in the U.S. gas turbine industry upon graduation. The trial program was successful in that several of the undergraduate fellows enjoyed the research work and applied to graduate school in the gas turbine area immediately following graduation. The undergraduate fellowship program is now an integral part of AGTSR. In fact, it is integrated into the RFP process; all proposals submitted as part of the RFP have an AGTSR fellowship program (up to \$6K per year) included in the cost budget profile. Therefore, the proposals selected for funding will automatically have the fellowship program in place when the AGTSR research subcontract becomes activated. This allows the fellows to begin their program in parallel to the research activity and also saves on administering a separate add-on scope of work to include a fellow after the subcontract had been awarded—which was the way the trial program was implemented.

The industrial internship program was initiated at the recommendation of the AGTSR Industrial Review Board and encompasses several positive attributes:

- motivational factor for engineering students within the United States
- encourages research and educational programs in land-based gas turbines and power generation systems
- enables professors to better understand and target research projects that would be directly beneficial to industry
- allows students to become more knowledgeable about power generation and gain hands-on and practical experience in an industrial setting

- allows companies to better evaluate and select top quality students to join their engineering or research staff
- promotes nationwide visibility of gas turbine engineering education.

A highly successful, one student per IRB member, trial internship program was established in 1995. Based on the initial success, the program was roughly doubled in FY96. In FY97, AGTSR placed 17 interns. To date, 37 AGTSR interns have been positioned at IRB company sites, and several of these interns have been hired directly by the sponsoring IRB companies.

Internship brochures have been assembled by AGTSR that describe the purpose of the program, participating industrial members, potential research and engineering projects, qualification requirements, and registration procedures. These brochures are distributed to the engineering departments of the AGTSR Performing Member Universities. The internship program is advertised in the late fall of each year with applications due in late March of the following year. The selection committee consists of the AGTSR principal investigator and program manager from SCERDC, and the seven industrial board members representing each of the sponsoring companies.

Selected interns are paid a weekly stipend of \$450, subject to withholding tax. The FY95 internship was for an 8 week period during the summer, but due to the recommendation of industry and the interns, that period was extended to 10 weeks in FY96, with a \$1000 allowance added to help offset travel and lodging expenses. In FY98, the internship experience may be extended to a 12 week period.

Applicants must be U.S. citizens or permanent resident aliens from accredited U.S. colleges or universities. The application package consists of an application form, description of research interests and career plans form, two engineering reference recommendations (advisor and engineering professor preferred), and official transcripts from all colleges and universities attended.

To date, AGTSR has received strong support for the fellowship and internship programs; it has improved industry-university linkages, and has motivated undergrads to enroll in graduate school and has leveraged add-on support from industrial sponsors to conduct more fundamental and applied research in advanced land-based gas turbine systems. In general, the AGTSR internship and research programs have had substantial impact on the relevance and effectiveness of the research and gas turbine education being conducted at the university level.

Project Accomplishments in 1997

The accomplishments of the AGTSR program in this reporting period are highlighted below in the following categories: Administration, Membership, Research, Workshop/Education and Miscellaneous Activity.

Administration

AGTSR's five-year renewal request to continue the AGTSR consortium until the year 2001 was approved by DOE-FETC and Headquarters. During the renewal request review period, full funding for AGTSR was not available. This slowed progress considerably and funding for the 1996 research awards were withheld by AGTSR until funding was available. The 1996 research awards were initiated in June 1997.

The AGTSR received 52 proposals in response to the 1997 RFP solicitation. The topical distribution was as follows: 22 in combustion, 20 in heat transfer, and 10 in materials. These projects were reviewed at SCERDC by the IRB and 10 projects were down selected for possible funding.

Final reports from Performing Member institutions are now being received and distributed. Reports from MIT, Texas A&M, Penn State, Lehigh University have already been distributed, with annual reports from Purdue, Cal-Irvine, Minnesota, Carnegie Mellon, Clemson, Georgia Tech, Maryland, and Oklahoma due the fourth quarter 1997. Mechanisms to gauge relevance to industry needs are now being developed as final research reports are now expected to be a regular occurrence.

AGTSR quarterly reports for the periods of January - March, and April - June have now been released to DOE. The 3rd quarterly report will be released in October 1997.

Membership

During this report period, the Performing Member university base has expanded to include the following:

University of Colorado (Boulder)	University of Kentucky
University of South Alabama	Colorado State University
University of California, Santa Barbara	Rensselaer Polytechnic Institute
Wichita State University	University of Tennessee

The Performing Member AGTSR institution has grown to 92, giving AGTSR a presence in 37 states.

The affiliate corporate membership admitted Southern Company Services to a six-month trial program. Fluent has expressed possible interest in affiliate membership with a corporate decision due the 4th quarter 1997. AlliedSignal Engine Company withdrew membership in the AGTSR consortium due to corporate budget cuts. However, AlliedSignal has expressed desire to renew membership in 1998. As of the end of the third quarter 1997, all AGTSR cost-sharing membership fees have been received and EPRI and GRI continue as AGTSR advisors.

Research

Brigham Young University, which is completing a four-year effort, received a no-cost extension until December 31, 1997. Final reports from MIT, Texas A&M, Penn State and Lehigh University have already been received and distributed to the IRB. MIT's project was terminated a year early by the IRB, therefore, they only reported on the aerodynamic measurements using Particle Image Velocimetry (PIV) to obtain planar velocity profiles in a rotating, internal passageway. The corresponding heat transfer study, Phase II of the project, will not be supported by AGTSR, but MIT has promised AGTSR access to these results when completed. The Texas A&M project dealt with the effects of rotation on cooling passage heat transfer with different enhancement geometries, and the effects of TBC spallation on surface heat transfer. Also, in their unsteady aerodynamics study, they developed an unsteady transition model and correlations which were implemented into a heat transfer calculation code. The Penn State project developed a thermo-mechanical-fatigue (TMF) crack growth model and a new life prediction model to account for thermomechanical strain cycling under realistic conditions. The Lehigh project focused on producing advanced TBC's using two Functionally Graded Materials (FGM) production methods—Reaction-Bonded Metal Oxide (RBMO) and electrochemical processing.

The following final reports are due by year end: Berkeley, Louisiana State, Purdue, and VPI. Also, additional funding support for Professor Ron LaFleur of Clarkson University has been approved. Effective July 1, 1997, Professor LaFleur will be doing a one-year sabbatical at P&W/West Palm Beach in conjunction with an AGTSR intern student that will work for 10 weeks during the summer of 1997. LaFleur will be working on longer term research projects in the aero-heat transfer area in coordination with Fred Soechting and Mark Zeleksy of P&W.

The FY95 AGTSR semi-annual progress reports have all been received and were distributed to the IRB and DOE-FETC in June 1997. The Clemson FY94 (film-cooling research project) annual and semi-annual reports (over a year delinquent) have now been received and reviewed by the IRB. The IRB approved both reports and, as a result, their outstanding invoices and amendments were processed.

The FY94 final reports are due during the fall of 1997. The following FY94 projects are still active: Purdue, Cal-Irvine, Minnesota, Carnegie Mellon, Clemson, Georgia Tech, Maryland, and Oklahoma. No-cost extensions have been approved for UC-Irvine and Minnesota until November 30, 1997, and December 31, 1997, respectively.

The AGTSR Industrial Review Board (IRB) has selected nine new research projects from the 1996 RFP solicitation. DOE-FETC has approved these nine new projects, and since full FY97 support has recently been secured, the nine new subcontracts have been awarded with an effective start date of June 13, 1997. These new projects are from the following universities: Cal-Davis (aerodynamics), Cleveland State (TBC's), Cornell (combustion), MIT (aerodynamics), Northwestern (TBC's), Penn State (combustion), Pittsburgh (TBC's), Purdue (combustion), and Wisconsin (aero-heat transfer).

Workshops/Education

The proceedings for Heat Transfer Workshop II were released during June to all 80 participants. The Proceedings consist of two volumes, including a short summary by the Clemson University technical hosts of the key points brought forth during the Workshop. Edge-cooling heat transfer in the endwall, trailing edge, and blade-tip regions was emphasized by industry as being a very important area to pursue during the next few years to support ATS and future programs; and as a result, this topic was listed in AGTSR's 1997 RFP announcement. The majority of the participants recommended that AGTSR host the heat transfer workshop on an annual basis, or at least every eighteen months. Consequently, AGTSR is considering their next workshop for early Fall of 1998, hosted with the University of Texas at Austin.

Another productive Combustion Workshop for AGTSR took place on March 5-7, 1997, in Atlanta, Georgia, co-hosted with Professor Ben Zinn of Georgia Tech. The Proceedings for this workshop were distributed in July 1997. The industry-university interactions were substantial and were especially lively in the catalytic combustion session, which is considered an enabling technology to satisfy the ultra-low NOx emissions capability for advanced land-based gas turbines. The AGTSR Combustion Workshop will be held on an annual basis. Planning for Combustion Workshop V is underway with our co-host being Dr. Robert Dibble of UC-Berkeley in California. The dates are set for March 25-27, 1998, at the Berkeley Marriott facility.

On August 6-7, 1997, AGTSR hosted its first short course. The topic for the course was Film Cooling. The course was held at Clemson University's Madren Conference Center and had 24 attendees, mostly from industry. The course was well received and AGTSR received numerous suggestions for other courses. As with the two workshops, course notes are available.

Starting in June 1997, AGTSR placed 17 interns at ATS company sites to gain hands-on, practical experience in an industrial setting. Twenty-one applications were received this year from the 90 AGTSR Performing Members. The IRB reviewed and rank-ordered the applications in April 1997 and AGTSR announced the selection of interns in May 1997. AGTSR sees the Industrial Internship Program as a motivational factor for engineers to encourage research and education in gas turbines, define relevant research projects, and provide an opportunity to see various engineering career paths in design, testing, R&D, and advanced technology. To date, AGTSR has placed 37

interns at ATS industrial sites. Of the 17 interns placed this summer, 6 were in the combustion area, 7 in heat transfer, and 4 in CFD/materials. The interns will finish their 10-week tour in mid-to-late August and they are required to give an oral presentation to industry on their technical accomplishments and the value of the program relative to its research and educational merit. AGTSR will receive written, 3-5 page summary reports from each intern.

Professor Ron LaFleur of Clarkson University began a 12-month sabbatical with P&W at West Palm Beach, Florida, in collaboration with their Connecticut facility. He will investigate several aero-heat transfer projects of direct interest to the engineers and designers of P&W's advanced product development office. Support for the sabbatical is expected from Clarkson, P&W, and AGTSR as part of a trial industry-faculty educational program that complements the graduate-level industrial internship program.

Miscellaneous

SCERDC presented a poster display at the second U.S. DOE Industrial Energy Efficiency Symposium and Expo on February 24-26, 1997, in Arlington, Virginia. The SCERDC poster included information and material on the AGTSR program, as well as the Pulsed Combustion Fluidized Bed Demonstration project and the Waste Technology Program (WTP). The meeting was quite successful with several hundred people participating—showcasing their advanced technologies, products, and services to meet the emerging energy, environmental, and market needs of U.S. industry.

AGTSR participated in the Midsize Gas Turbine (MGT) planning workshop in Sacramento, California, on March 4-5, 1997. MGT is being considered as a possible sequel to the ATS program, in the 30-150MW range, to meet the need for intermediate-load, repowering, and more flexible gas turbine products for the next century. MGT would probably be an aero-derivative program with intercooling and possibly a humid air turbine cycle. It may also include an R&D element similar to the AGTSR arm of ATS. This new program has been endorsed by the Gas Turbine Association (GTA) with potential support for MGT coming from the California Energy Commission (CEC).

AGTSR attended the Sensors and Controls Workshop offered by NIST, August 25-26, 1997, in Gaithersburg, Maryland. The purpose of the workshop was to discuss the measurement, sensor, control and robotic needs of both the power generation and process industries as supported by DOE-OIT. The technical sessions in this workshop could also support a new AGTSR initiative in sensors and controls being considered by DOE-FETC and ORNL.

AGTSR participated in three ways at the TurboExpo in Orlando, Florida, this summer: displaying an exhibit booth on the AGTSR consortium, presenting a paper in the education session, and taking part in an ATS panel session. The exhibit booth displayed some of the research successes of AGTSR in the various discipline areas: combustion, aerodynamics, heat transfer, and materials. Some hardware items, such as combustion sensors and heat pipe cooling vanes, were also displayed at the booth. The AGTSR paper was entitled, "AGTSR: A Unique Gas Turbine Consortium." The paper emphasized both the educational and research missions of AGTSR. It also highlighted the status of the consortium and discussed the effectiveness and impact of the industrial internship program which targets graduate-level students within the AGTSR performing members. In the ATS panel session, AGTSR discussed their unique role in support of ATS and provided some examples of successful research collaboration with industry and universities as fostered by the AGTSR consortium. AGTSR Performing Member institutions presented 26 papers at the IGTI Conference.

AGTSR will again host a poster session at the ATS Annual Review Meeting in Morgantown, West Virginia, October 28-29, 1997. A tentative agenda that includes 29 research posters has already

been submitted to DOE-FETC's conference services office who are organizing the ATS Review this year. In addition to the poster session, AGTSR will present an AGTSR update paper and host an industry panel session that will review AGTSR success stories.

An AGTSR program review at DOE-FETC was held August 29, 1997. The purpose of the review was to brief the DOE-ATS team on the SCERDC organization, the AGTSR proposal review process, AGTSR technical successes, and the future role of AGTSR and SCERDC after ATS comes to completion. Notes of the review meeting are available.

AGTSR Future Activities

Under Cooperative Agreement DE-FC21-92MC29061, Advanced Gas Turbine Systems Research, the South Carolina Energy Research and Development Center has assembled a unique industry/university/government research consortium. The program has developed into a smooth functioning productive consortium. The AGTSR is highly industry leveraged and specifically designed to support the advancement of power generation via land based gas turbines.

The AGTSR goals for 1998 are summarized in the following paragraphs under headings of Administration, Membership, Research, Workshop/Education and a brief section of Miscellaneous activity.

Administration

Through calendar year 1998, the South Carolina Energy Research and Development Center will continue to function as the administrative headquarters for AGTSR. The AGTSR will be coordinated through the Office of the Director of SCERDC (Dr. L.P. Golan) with Dr. Daniel B. Fant continuing to serve as the AGTSR Program Manager. Additional staff from SCERDC will be provided on an as-needed basis. As opportunity permits, SCERDC will engage a half-time employee to assist in enhancing the AGTSR technology transfer activities. The Industrial Review Board (IRB) will continue to function in the role of providing direction and selection for program activities. DOE-FETC will continue to provide program oversight and approval of activities. The Performing Member institutions will continue in their role of actual "doers" of the research work.

The major activities will include, but not be limited to, the following:

- coordination/preparation of 1998 RFP review/award process
- completion of negotiations for 1997 research awards
- monitoring and distribution of results from ongoing research
- preparation of success stories for DOE
- reporting financial progress of subcontracts to DOE
- overseeing workshops/short courses/fellowships
- maintain communication link between all program parties
- responding to DOE requests as needed
- participation in Annual ATS Review, IGTI Meeting and other meetings as appropriate.

Membership

The AGTSR will not be actively seeking new Performing Member institutions; however, as individual applications are received from universities, their requests will be reviewed and appropriate action taken. It is expected that the Performing Member Notebook will be updated and redistributed in 1998. This is necessary due to Performing Member growth in 1997.

Affiliate members to AGTSR will be actively sought. AGTSR will encourage Southern Company Services to extend their trial membership and the inquiry from Fluent will be pursued. AlliedSignal, who withdrew membership in 1997 due to corporate budget cuts, will be encouraged to consider membership renewal. All corporate memberships will be coordinated with DOE/IRB prior to admission to the program.

Research

At the IRB Research Proposal Review Meeting held at SCERDC on September 4-5, 1997, the proposals shown in Table IV were recommended for funding by the IRB. The SCERDC will begin negotiations with the PI/Universities so indicated with the intent of issuing subcontracts for the research shortly after receiving approval and budget from DOE for 1998.

At the IRB Meeting, the IRB approved the release of the next call for proposals in March 1998.

The AGTSR, with the assistance of the IRB, will develop a mechanism to gauge relevance of the completed university projects.

Table IV
Recommended List of Research Programs - 1997

<u>University/PI</u>	<u>Technical Objective</u>	<u>Total Requested \$K's</u>
University of California/Samuelsen	Combustion: Gas Composition Effects	696
Cal Tech/Culick	Non-uniformity of Mixture Ratio in Lean PM Combustion	390
VPI/Vandsburger	Reduced-Order Models for CI Prediction	603
Purdue/Fleeter	Turbine Blade Tip, Endwall and Platform Heat Transfer	573
University of Minnesota/Goldstein	Edge Cooling Heat transfer in Turbine Blades	497
Carnegie Mellon/Chyu-Simon	Nozzle Endwall Region	560
Purdue/Plesnick	Airfoil Trailing Edge Cooling	160
Georgia Tech/Hampikian	Improvement in TBC's via Combustion CVD	441
UCSB/Levi	Life Prediction and NDE for TBC's	600
University of Central FL/Desai	NDE of TBC's by Electro-Chemical Impedence	198

Workshops/Education

At the September IRB Meeting, the fifth combustion workshop was approved. This workshop will be hosted with the University of California-Berkeley in March 1998. The IRB also approved the third heat transfer workshop. The IRB recommended that this workshop be held no earlier than the fall of 1998. AGTSR will enter into negotiation with University of Texas at Austin and the University of Wisconsin, as a team, to co-host the Heat Transfer Workshop III. The proposed location is Austin, Texas. The IRB also approved a TBC Specialty Workshop to review select AGTSR TBC projects and explore bond cost issues. A potential co-host for this specialty meeting is Stevens Institute of Technology with late spring 1998 as a potential date.

Open issues proposed by the IRB for AGTSR to consider were the following two items: (1) Could a Sensors Workshop be offered in 1998 and (2) Could a new short course on heat transfer or other topic area be developed in 1998? Both topics will be explored by AGTSR with suggested opportunities reviewed with the DOE/IRB prior to finalization of plans.

Finally, the IRB recommended expansion of the Internship Program for graduate students and faculty in 1998. The summer student program will be extended from 10 to 12 weeks, with a 15 to 20 student target. AGTSR will also explore opportunities to continue the faculty fellowship program. A target of one to two faculty members for the academic year and/or summer was established.

Miscellaneous Activity

The AGTSR will continue to participate in opportunities to expand the programs as they occur. Other than release of *Update*, the AGTSR newsletter, no specific miscellaneous functions are now known. However, as examples of activities that have occurred, AGTSR has participated in the DOE/OIT Symposium and Expo on Industrial Energy Efficiency, AGTSR participated in Midsize Gas Turbine planning workshop hosted by DOE and the California Energy Commission and AGTSR participated in the NASA film cooling workshop hosted by Ohio Aerospace Institute. Events such as these will continue. AGTSR does plan to participate in the Active Combustion Control Seminar sponsored by the Navy-China Lake and hosted by NASA-Lewis on November 12, 1997.

Also, at no cost to the AGTSR program, SCERDC will maintain membership and participate in the Gas Turbine Association, the Association of State Energy Research and Technology Transfer Institutions and the EPRI sponsored Council of Consortia CEO's.

Acknowledgements

The DOE research support provided to the South Carolina Energy Research and Development Center is gratefully acknowledged. SCERDC also acknowledges the support and assistance of the DOE-FETC Project Managers, Norman Holcombe, Abbie Layne and Charles Zeh. In addition, SCERDC greatly appreciates the valuable assistance provided by our Industrial Review Board Members: Sy Ali, Paul Bautista, Michael Benjamin, Charles Boohaker, Arthur Cohn, William Day, Ihor Diakunchak, Harold Miller, George Padgett, Curt Scheuerman, and David Winstanley.

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